DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

JACKSON FOLIO
CALIFORNIA

INDEX MAP

SCALE: 40 MILES-1 INCH

AREA OF THE JACKSON FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION TOPOGRAPHY AREAL GEOLOGY ECONOMIC GEOLOGY STRUCTURE SECTIONS

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EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined and those which are most important are stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and so on with any other contour. In the space between any two contours occur all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines and define all prominences. The relations of contour characters to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$, the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

Culture.—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$, to about four square miles; and on the scale of $\frac{1}{250,000}$, to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. These areas correspond nearly to 4000, 1000 and 250 square miles.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the states, counties or townships. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes. The Appalachian mountains would become an archipelago in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses; and as it rises or subsides the shore lines of the oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

PERIOD.	SYMBOL.	COLOR—PRINTED IN PATTERNS OF PARALLEL LINES.
Neocene (youngest).	N	Yellowish buff.
Eocene	E	Olive-brown.
Cretaceous	K	Olive-green.
Juratrias	J	Gray-blue-green.
Carboniferous	C	Gray-blue.
Devonian	D	Gray-blue-purple.
Silurian	S	Gray-red-purple.
Cambrian	Є	Brown-red.
Algonkian (oldest).	A	Orange-brown.

In any district several periods may be represented, and the representation of each may include one or many formations. To distinguish the sedimentary formations of any one period from those of another, the patterns for the formations of each period are printed in the appropriate period-color; and the formations of any one period are distinguished from one another by different patterns. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

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DESCRIPTION OF THE GOLD BELT.

GEOGRAPHIC RELATIONS.

The Gold Belt of California includes that portion of the Sierra Nevada lying between the parallels of 37° 30′ and 40°. This area is bounded on the east by the Great Basin and on the west by the Great Valley of California, comprising about 17,000 square miles. The Sierra Nevada here forms a single range, sloping somewhat abruptly toward the Great Basin and gradually toward the Great Valley of California. Within this area lie the chief gold deposits of the State, though by no means all of the area is auriferous. At the northern limit the deposits are scattered over nearly the entire width of the range, while to the south the productive region narrows to small dimensions. The mass of the range south of Alpine County is comparatively barren. North of the 40th parallel the range is probably not without deposits, but the country is flooded with lavas which effectually bury them.

GENERAL GEOLOGY.

The rocks of the Sierra Nevada are of many kinds and occur in very complex associations. They have been formed in part by deposition beneath the sea, and in part by intrusion as igneous masses, as well as by eruption from volcanoes, and portions of them have been subsequently metamorphosed.

The southern portion of the range is composed of granite. The central and northern part, west of longitude 120° 30′, consists prevailingly of schists, which have been produced by intense metamorphism of both ancient sediments and igneous rocks, and it is chiefly but not solely in these schists that the auriferous quartz veins occur. The trend of the bands of altered sediments and of the schistose structure is generally from northwest to southeast, parallel to the trend of the range, but great masses of granite and other igneous rocks have been intruded among these schists, forming irregular bodies which interrupt the regular structure and which are generally bordered each by a zone of greater metamorphism. These schists with their associated igneous masses form the older of two great groups of rocks recognized in the Sierra Nevada. This group is generally called the Bed-rock series.

Along the western base of the Sierra occur beds of sandstone and clay, some of which contain thin coal seams. These are much younger than the mass of the range and have not shared the metamorphism of the older rocks. They dip gently westward beneath the later deposits, which were spread in the waters of a shallow bay occupying the Valley of California and portions of which have been buried beneath recent river alluvium.

Streams flowing down the western slope of the Sierra in the past distributed another formation of great importance—the Auriferous gravels. The valleys of these streams served also as channels for the descent of lavas which poured out from volcanoes near the summit. Occupying the valleys, the lavas buried the gold-bearing gravels and forced the streams to seek new channels. These have been worn down below the levels of the old valleys, and the lava beds, with the gravels which they protect, have been isolated on the summits of ridges. Thus the Auriferous gravels are preserved in association with lavas along lines which descend from northeast toward southwest, across the trend of the range. The nearly horizontal strata, together with the Auriferous gravels and later lavas, constitute the second group of rocks recognized in the Sierra Nevada. Compared with the first group, the Bed-rock series, these may be called the Superjacent series.

The history of the Sierra Nevada, even so far as it is recorded in the rocks, has not yet been fully made out; but the events of certain epochs are recognized, and these may be stated in a brief summary in the order in which they occurred.

THE PALEOZOIC ERA.

During the Paleozoic era, which includes the periods from the end of the Algonkian to the end of the Carboniferous, the State of Nevada west of longitude 117° 30′ appears to have been dry land of unknown elevation. This land probably extended westward into the present State of California and included part of the area now occupied by the Sierra Nevada. Its western shore was apparently somewhat west of the present crest, and the sea extending westward received Paleozoic sediments which now constitute a large part of the central portion of the range.

At the close of the Carboniferous the Paleozoic land area of western Nevada subsided, and during a portion or all of the Juratrias period it was at least partly covered by the sea. At the close of the Juratrias, according to the latest paleontological determinations, the Sierra Nevada was upheaved as a great mountain range, the disturbance being accompanied by the intrusion of large amounts of granite.

The Auriferous slate series comprises all of the sedimentary rocks that entered into the composition of this old range of Juratrias time. Formations representing the Algonkian and all of the Paleozoic and Juratrias may therefore form part of the Auriferous slate series.

Fossils of Carboniferous age have been found in a number of places, and the presence of Silurian beds at the northeast base of the range has been determined. A conglomerate occurs in the foothills of Amador and Calaveras counties, interbedded with slates containing Carboniferous limestone; this conglomerate is therefore presumably of Carboniferous age. The conglomerate is evidence of a shore, since it contains pebbles of quartzite, diabase, and hornblende-porphyrite, which have been rounded by the action of waves. The presence of igneous pebbles in the conglomerate shows that volcanic eruptions began at a very early date in the formation of the range, for the hornblende-porphyrite pebbles represent lavas similar to the hornblende-andesites of later age.

The Paleozoic sediments of the Gold Belt consist of quartzite, mica-schist, and clay-slate, with limestone lenses. Rounded crinoid stems, *Lithostrotion*, *Fusulina*, *Clisiophyllum*, *Spirifera*, and other genera have been found, chiefly in the limestone, and indicate that the age of the rocks is Carboniferous. The Paleozoic sediments are finely exposed in Calaveras County, and on the Gold Belt sheets they will be designated the Calaveras formation. It is probable that some areas mapped as Calaveras may contain strata earlier or later than the Carboniferous.

During an epoch of upheaval some time after the close of the Carboniferous period, these sedimentary strata were raised, forming part of a mountain range. The beds were folded and compressed, and thus rendered schistose. Granite and other igneous rocks were intruded among them, and they assumed somewhat the relations which they now exhibit in the Sierra Nevada. But those masses which now form the surface were then deeply buried in the foundations of the range. They have been brought to the present surface by subsequent uplifts and prolonged erosion.

JURATRIAS PERIOD.

The areas of land and sea which existed during the earlier part of this period are scarcely known. Strata showing the former presence of the sea have been recognized in the southeastern portion of the range at Mineral King, where the sediments are embedded in eruptive granite, and at Sailor Canyon, a tributary of American River. Rocks of this age occur generally throughout the Great Basin and the Rocky Mountains, but the interior sea or archipelago in which they were deposited was apparently separated from the Pacific by a land mass stretching the length of the Sierra Nevada. This land probably originated in the upheaval above referred to, some time after the close of the Carboniferous, and toward the end of the Juratrias period its area became so extensive that the waters of the Pacific seem to have been completely separated from the interior seas. This conclusion is based upon the fact that fossils of Jurassic age in California, so far as known, have closer relations with those of Russia than with those of eastern America.

The genus *Aucella*, whose shells occur in Russia, flourished on the Pacific Coast until well into the Cretaceous, and is distributed from Alaska to Mexico. In the Juratrias strata of California it is associated with ammonites of the genera *Perisphinctes*, *Cardioceras*, and *Amaltheus*, which are closely related to forms of the European Upper Jurassic.

The strata in which these fossils occur are prevailingly clay-slates, which are locally sandy and contain pebbles of rocks from the Calaveras formation. Thus it is evident that they were deposited near the shore of a land composed of more ancient schists, and the generally fine character of the sediment shows that the land which occupied the area of the Sierra Nevada can not have been very mountainous. These strata now occur in two narrow bands along the western base of the range, and are called the Mariposa formation, from the fact that they are well exposed near Mariposa.

Soon after the Mariposa formation had been deposited the region underwent uplift and compression. The result of uplift was the development of a mountain range along the line of the Sierra Nevada. The Coast Range also was probably raised at this time. The action of the forces was such as to turn the Mariposa strata into a vertical position, shattering the rock and deforming it, and producing some metamorphism. The clay-shales now have a slaty structure, produced by pressure, which appears to coincide in most cases with the bedding. It was a time of intense eruptive activity. The Mariposa beds were injected with granite, and vast masses of diabase, associated with other basic igneous rocks, date from this time. There is evidence that igneous rocks were intruded in varying quantities at different times; but that the intrusion of the great mass of the igneous rocks accompanied or immediately followed the upheavals is reasonably certain.

The Mariposa beds carry numerous gold veins, the most important group of which constitutes the famous "Mother lode." It is believed that most of the gold veins were formed after this upheaval and as a consequence of it, occupying fissures opened during the uplift.

The disturbance following the deposition of the Mariposa beds was the last of the movements which produced the vertical arrangement of the Auriferous slate series. The strata of succeeding epochs are sediments and tuffs. Lying nearly horizontal or at low angles, they prove that since they were accumulated the rock mass of the Sierra Nevada has not undergone much compression. But the fact that they now occur high above sea-level is evidence that the range has undergone elevation in more recent time.

CRETACEOUS PERIOD.

By the close of the Juratrias the interior sea of North America had receded from the eastern base of the Sierra Nevada eastward beyond the Rocky Mountains. From the western part of the continent the waters of the Pacific had retired in consequence of the Juratrias uplift. The Valley of California was then partly under water, and the Coast Ranges seem to have been represented by a group of islands, but during the later Cretaceous the region subsided and the sea substantially overflowed it. Through gradual changes of level the areas of deposition of marine sediments were shifted during the Cretaceous and Neocene periods, and late in the Neocene the sea once more retreated west of the Coast Ranges. The deposits laid down during this last occupation of the Valley of California belong to the Superjacent series.

The advance of the sea spread a conglomerate over the eastern part of the valley in later Cretaceous time, and sandstone and shale were subsequently deposited. This formation is well developed near Chico, and at Folsom, on the Sacramento sheet. It has been called the Chico formation.

EOCENE PERIOD.

In consequence of slow changes of level without marked disturbance of the Chico formation, a later deposit formed, differing from it somewhat in extent and character. The formation has been called the Tejon (Tay-hone). It appears in the Gold Belt region at the Marysville Buttes, and it is extensively developed in the southern and western portions of the Valley of California.

NEOCENE PERIOD.

The Miocene and Pliocene ages, forming the later part of the Tertiary era, have in this atlas been united under the name of the Neocene period. During the whole of the Neocene the Great Valley of California seems to have been under water, forming a gulf connected with the sea by one or more sounds across the Coast Ranges. Along the eastern side of this gulf was deposited during the earlier part of the Neocene period a series of clays and sands to which the name Ione formation has been given. It follows the Tejon, and appears to have been laid down in sensible conformity to it. Marine deposits of the age of the Ione formation are known within the Gold Belt only in the Marysville Buttes. Along the eastern shore of the gulf the Sierra Nevada, at least south of the 40th parallel, during the whole of the Neocene, and probably also during the Eocene and latest Cretaceous, formed a land area drained by numerous rivers. The shore-line at its highest position was several hundred feet above the present level of the sea, but it may have fluctuated somewhat during the Neocene period. The Ione formation appears along this shore-line as brackish-water deposits of clays and sands, and frequently it contains beds of lignite.

The drainage system during the Neocene had its sources near the modern crest of the range, but the channels by no means coincided with those of the present time. The Auriferous gravels for the most part accumulated in the beds of these Tertiary rivers, the gold being derived from the croppings of veins. Such gravels could accumulate only where the slope of the channel and the volume of water were sufficient to remove the silt while allowing the coarser or heavier masses to sink to the bottom with the gold.

The climate of the late Neocene was warm and humid, much moister than it would have been if the Great Valley had been above water, and erosion was correspondingly rapid.

A mountain-building disturbance occurred during the Neocene period. This was caused by pressure acting from the SSW. toward the NNE. with a downward inclination. One effect of this pressure was to induce movements on a network of fissures, often of striking regularity, intersecting large portions of the range. It is not improbable that this fissure system originated at this time, but there are fissures of greater age. This disturbance also initiated an epoch of volcanic activity accompanied by floods of lavas* consisting of rhyolite, andesite, and basalt, which continued to the end of the Neocene. These lavas occupy small and scattered areas to the south, increasing in volume to the north until, north of the 40th parallel, they cover almost the entire country. They were extruded mainly along the crest of the range, and often followed fissures belonging to the system mentioned above. The recurrent movements on the fissures were probably accompanied by an increase in the development of the fissure system. An addition to the gold deposits of the range attended this period of volcanic activity.

When the lavas burst out they flowed down the river channels. Sometimes they were not sufficient to fill the streams, and are now represented by layers of "pipe clay" or similar beds in the gravels. These minor flows were chiefly rhyolite. The later andesitic and basaltic eruptions were of great volume, and for the most part completely choked the channels into which they flowed. The rivers were thus obliged to seek new channels—substantially those in which they now flow.

Fossil leaves have been found in the pipe clay and in other fine sediments at numerous points. Magnolias, laurels, figs, poplars, and oaks are represented. The general facies of the flora is thought to indicate a low elevation, and has been compared with that of the flora of the South Atlantic Coast of to-day.

PLEISTOCENE PERIOD.

During Cretaceous and Tertiary time the older

*The term "lavas" is here used to include not only such material as issued from volcanic vents in a nearly anhydrous condition and at a very high temperature, but also tuff-flows and mud-flows, and, in short, all fluid or semifluid effusive volcanic products.

Sierra Nevada had been reduced by erosion to a range with gentle slopes. An elevation of the range doubtless attended the Neocene disturbance above referred to, and minor dislocations probably recurred at intervals; but at the close of the Tertiary a greater uplift occurred, which was accompanied by the formation of normal faults. These were widely distributed throughout the range, particularly along the eastern escarpment, where they form a well-marked zone to the west of Mono Lake and Owen Lake. As a consequence of this elevation the streams, having greater fall, cut new and deep canyons in the hard but shattered base of the preexisting mountains.

A period of considerable duration elapsed between the emission of the lava flows which displaced many of the rivers and the time at which the higher Sierra was covered by glaciers. In the interval most of the deep canyons of the range were cut out. Such, for example, are the Yosemite Valley on the Merced River, the great canyon of the Tuolumne, and the canyon of the Mokelumne. The erosion of these gorges was often facilitated by the fissure system referred to above, and many of the rivers of the range follow one or other set of parallel fissures for a long distance.

It is a question at what point the limit between the Neocene and Pleistocene should be drawn. It has become usual to regard the beginning of the Glacial epoch in eastern United States as the close of the Neocene. If it could be shown that the glaciation of the Sierra was coeval with that of northeastern America a corresponding division would be adopted. It is believed, however, that glaciation was much later in California than in New England, and that the great andesitic flows mark the close of the Neocene.

The Sierra, from an elevation of about 5,000 feet upwards, was long buried under ice. The ice did not to any notable extent erode the solid rock in the area which it covered, although it removed enormous amounts of loose material. It seems rather to have protected it from erosion while intensifying erosion at the lower elevations, just as would a lava cap. Small glaciers still exist in the Sierra.

There is no valid reason to believe that the Sierra has undergone any great or important dynamic disturbance since the beginning of glaciation. The whole mass, however, has risen bodily a few hundred feet during that time, as is shown by elevation of the Pleistocene shore gravels in the foothill region, by the raised beaches along the coast-line of California, by recent shells in the Contra Costa Hills, and by other significant indications.

IGNEOUS ROCKS.

Rocks of igneous origin form a considerable part of the Sierra Nevada. The most abundant igneous rock in the Sierra Nevada is granite, this term embracing both granodiorite and true granites. Rocks of the granitic series are believed to have consolidated under great pressure and to have been largely intruded into overlying formations at the time of great upheavals. Thus granite is a deep-seated rock, and is exposed only after great erosion has taken place.

The rocks called diabase and augite-porphyrite on the Gold Belt maps are not always intrusive, but to some extent they represent surface lavas and correspond to modern basalt and augite-andesites. In like manner, some of the hornblende-porphyrites correspond to hornblende-andesites.

GLOSSARY OF ROCK NAMES.

The sense in which the names applied to igneous rocks have been employed by geologists has varied and is likely to continue to vary. The sense in which the names are employed in this series of sheets is as follows:

Gabbro.—A granular intrusive rock consisting principally of diallage or allied monoclinic pyroxene, or a rhombic pyroxene, together with soda-lime and lime feldspars.

Gabbro-diorite.—A term used to indicate areas of gabbro containing primary and secondary hornblende and areas containing intimate mixtures of gabbro and diorite.

Pyroxenite.—A granular intrusive rock composed principally of pyroxene.

Peridotite.—A granular intrusive rock generally composed principally of olivine and pyroxene, frequently of olivine alone.

Serpentine.—A rock composed of the mineral serpentine, and often containing unaltered remains of feldspar, pyroxene, or olivine. Serpentine is frequently a decomposition product of rocks of the peridotite and pyroxenite series.

Diorite.—A granular intrusive rock consisting principally of soda-lime feldspar and hornblende.

Granodiorite (quartz-mica-diorite).—A granular intrusive rock having the habitus of granite and carrying feldspar, quartz, biotite, and hornblende. The soda-lime feldspars are usually considerably and to a variable extent in excess of the alkali feldspars. This granitic rock might be called quartz-mica-diorite, but this term, besides being awkward, does not sufficiently suggest its close relationship with granite; it has therefore been decided to name it "granodiorite."

Granite-porphyry.—A granite with large porphyritic potash feldspars.

Amphibolite, amphibolite-schist.—A massive or schistose rock composed principally of green hornblende, with smaller amounts of quartz, feldspar, epidote, and chlorite, and usually derived by dynamo-metamorphic processes from diabase and other basic igneous rocks.

Diabase.—An intrusive or effusive rock composed of augite and soda-lime feldspar. The augite is often partly or wholly converted into green, fibrous hornblende, or uralite.

Augite-porphyrite.—A more or less fine-grained rock of the diabase series, with porphyritic crystals of augite and sometimes soda-lime feldspars.

Hornblende-porphyrite.—An intrusive or effusive porphyritic rock consisting of soda-lime feldspars and brown hornblende in a fine groundmass.

Quartz-porphyrite.—An intrusive or effusive porphyritic rock consisting of quartz and soda-lime feldspar, together with a small amount of hornblende or biotite. It is connected by transitions with granodiorite and with the following:

Quartz-augite-porphyrite.—This is the same as the above, except that it contains augite. It is connected by transitions with augite-porphyrites and with quartz-porphyrites.

Quartz-porphyry.—An intrusive or effusive porphyritic rock, which differs from quartz-porphyrite in containing alkali feldspars in excess of soda-lime feldspars.

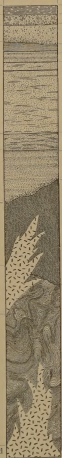
Rhyolite.—An effusive rock of Tertiary or later age. The essential constituents are alkali feldspars and quartz, usually with a small amount of biotite or hornblende in a groundmass, often glassy.

Andesite.—An effusive porphyritic rock of Tertiary or later age. The essential constituents are soda-lime feldspars and ferromagnesian silicates. The silica is usually above 56 per cent.

Basalt.—An effusive rock of Tertiary or later age, containing soda-lime feldspars, much pyroxene, and usually olivine. The silica content is less than 56 per cent. It is also distinguished from andesite by its structure.

GENERALIZED SECTION OF THE FORMATIONS OF THE GOLD BELT.

	Period.	Formation Name.	Formation Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
Superjacent Series.	Pleistocene	Recent.	al		1–100	Soil and gravel.
		River and shore gravels.	grv		1–100	Sand, gravel, and conglomerate.
	Neocene	River and shore gravels	Ng		10–400	Gravel, sandstone, and conglomerate.
		Ione.	Ni		10–100	Shale or clay rock.
					10–100	Sandstone.
					- - - - -	Coal stratum.
					50–800	Clay and sand, with coal seams.
	Eocene	Tejon.	Et		10–300	Sandstone and conglomerate.
	Cretaceous	Chico.	Kc		50–400	Tawny sandstone and conglomerate
						GREAT UNCONFORMITY
Bed-Rock Series	Juratrias	Mariposa.	Jm		1,000 or more	Black clay-slate, with interbedded greenstones and some conglomerate.
		Intrusive granitic rocks.	gr grd			UNCONFORMITY.
	Carboniferous and Older	Calaveras.	Cc		4,000 or more	Argillite, limestone quartzite, chert, and mica-schist, with interbedded greenstones.
		Intrusive granitic rocks.	gr grd			



DESCRIPTION OF THE JACKSON SHEET.

TOPOGRAPHY.

The area covered by the Jackson sheet embraces a portion of the foothills of the Sierra Nevada, and lies chiefly in the counties of Amador and Calaveras, California. The highest elevation is in the northeastern section, where Mount Crossman reaches an altitude of 3,985 feet, and the lowest is in the southwestern section, where the level land along the Calaveras River has an altitude of less than 200 feet above the sea. As in the other portions of the foothills, the rivers have in general a southwesterly course, and have cut deep canyons, resulting in a system of ridges with a northeast and southwest trend. This is brought out in a striking manner by the general course of the roads of the region, which usually follow the ridges. The ridges of the Bear Mountains and the Gopher Ridge, in the southern part of the sheet, with northwest and southeast trend, are marked exceptions to this general system, and the drainage is necessarily of the same trend as the ridges. These mountains form a barrier across the southwestern river system and deflect the drainage to the northwest and southeast.

The two principal rivers of the district are the Mokelumne and the Calaveras. The forks of the Mokelumne rise in the very crest of the Sierra Nevada, and its water supply is maintained during spring and summer by melting snow. The headwaters of the Calaveras, on the other hand, begin west of the main crest, and, not being fed by snow to any great extent, this river is nearly dry in late summer and early fall. The catchment basin of the Mokelumne comprises about 800 square miles, while that of the Calaveras comprises about 400 square miles. The volume of water carried by the Mokelumne is therefore greater than that carried by the Calaveras, and its value for irrigation purposes is proportionately greater. The lakes along the crest of the Sierra furnish an additional supply to the Mokelumne, whose branches tap them. Two of these, the Blue Lakes, serve as reservoirs for the Amador Canal, which supplies the chief mines of Amador County.

GEOLOGY.

BED-ROCK SERIES.

This series consists of sedimentary rocks which were forced into a nearly vertical position at or before the post-Jurassic upheaval, together with the associated igneous rocks.

AURIFEROUS SLATES.

Calaveras formation.—This group of rocks is finely exposed in the area of the Jackson sheet, particularly along the branches of the Calaveras River. As on the Placerville sheet, it is divided into two distinct belts, one lying west and the other east of the eastern belt of the Mariposa slates, which contains in part the famous Mother lode. Since these two belts differ in general character, they will be described separately.

The western belt of the Calaveras formation extends from the northwest base of the peak known as Bear Mountain—this being the highest point in the group of that name—to and beyond Bisbee Peak, continuing into the area covered by the Placerville sheet, where it has afforded a considerable number of species of Carboniferous fossils. The belt varies in width from half a mile to about 2 miles. West of Bear Mountain it has been replaced by igneous rocks of the diabase and porphyrite series, but a corresponding belt begins a little farther south. The two narrow areas of sedimentary rocks lying one 1 mile and the other 1½ miles southwest of Bear Mountain are thought to belong to this belt. The series is apparently conformable throughout, the strata having usually a strike of about north 25° west, and dipping to the east at an angle of from 50° upwards.

The rocks of the western belt comprise black clay-slate, argillaceous schist, quartzite, chert (phthanite), and lenses of limestone, with much fragmental volcanic material of the porphyrite series. Characteristic of this belt is a dark conglomerate, sometimes fine, sometimes coarse, which contains fragments and pebbles of porphyrite, pieces of blue limestone, and flakes of black shale. Some masses of this material are largely made up of porphyrite fragments, and have been mapped as igneous. Such material is represented on the map by the area 1 mile west of Bisbee Peak, that 1 mile west of Sugar Loaf, and portions of the large area just east of the Mountain Spring House, though in this latter area there is a good deal of compact porphyrite, which may represent contemporaneous lava-flows or dikes in the fragmental material. The western belt has been much cut up by intrusives—dikes and bosses of diabase, porphyrite, gabbro, and rocks of the peridotite series.

At numerous points in this western belt of the Calaveras formation fossils have been found in the limestone lenses. These have been referred by Mr. C. D. Walcott to the Carboniferous, and are as follows: *Fusulina cylindrica*, *Zaphrentis*(?), *Lithostrotion*(?), and crinoid stems. The *Fusulina* and the crinoid stems are the most abundant. According to Mr. Walcott, the genus *Fusulina* does not occur lower than the Carboniferous or higher than the upper division of that system, usually called the Permian.

An isolated area of the Calaveras formation, about 12 miles long and with an average width of half a mile, lies east of the high eastern ridge of the Bear Mountains. This is composed of black clay-slate, quartzite, and limestone lenses, and is likewise represented on the map as of Carboniferous age, although no fossils have been found in it. One of the limestone lenses, just east of the Kentucky House, is about 1½ miles in length. Immediately west of this long, narrow area are the black slates of the Mariposa beds. The exact boundary between these two sedimentary series was laid down with some hesitation, and may be modified hereafter.

The geographic extent of the eastern belt of the Calaveras formation is much greater than that of the western, and its northern, eastern, and southern limits lie outside the area covered by the Jackson sheet.

The eastern belt differs materially from the western, in that its rocks are much more altered and in that it contains little or none of the peculiar flake conglomerate with porphyrite fragments which is so abundant in the western belt. Except along its western border, it has been penetrated by but few dikes of basic intrusives, and these have been mostly metamorphosed into amphibolite-schists and chlorite-schists, amphibole-talc rocks, and serpentines.

The prevailing rocks are black micaceous slate—sometimes converted into mica-schist—quartzite, and limestone, the latter occurring in lenses, three of which—at Cave City, Volcano, and on the ridge north of Dry Creek—attain a length of 2 miles each. Much of the limestone has become crystalline, and may therefore be called marble.

The only fossils found in the portion of this eastern belt of the Calaveras formation which is represented on the Jackson sheet are crinoid stems, which occur in the limestone. The rounded form of these stems indicates, but does not make certain, the Paleozoic age of the limestone. In the Yosemite-sheet area, however, *Fusulina* was found in limestone at Hites Cove, near the southern end of this belt, so that there is no doubt of the Carboniferous age of a portion of the eastern area. Other portions are perhaps Juratrias in age; and rocks older than the Carboniferous may also be included within its limits.

Some small areas of amphibolite and of amphibole-talc rocks have been outlined within the central mass of the belt, but there are other areas of hornblendic and micaceous schists which probably represent what were originally basic igneous rocks, but which are now associated with schists representing original sediments, the whole series being so altered as to make their separation in the field a matter of great difficulty. The soil from these schists is usually of a deeper red than that formed from the sedimentary schists. They are believed to form an inconsiderable part of the area of the Calaveras formation here described.

The general trend of the strata of the eastern belt of the Calaveras formation is about north 20° west, with steep eastern dip; but large masses of the strata have been thrown into various positions, apparently by forces acting from the northwest or southeast, or from both directions. Thus the rocks to the north of Angels, along Calaveritas River and San Antonio and San Domingo creeks, have a strike a little north of west, and another large body along Dry Creek trends northeast.

The orogenic disturbances that produced these dislocations of the strata were accompanied or followed by the intrusion of large masses of igneous rocks, chiefly granodiorite (quartz-mica-diorite). The intrusion of these igneous masses has resulted in the metamorphism of the rocks of a very large part of the area.

Nearly all of the sedimentary rocks of the series are now more or less micaceous, and contact minerals (mica, chlorite, tourmaline, and garnet) have been developed in them, particularly but not solely near the granitic masses. These contact minerals are presumed to be the product of mineralizing solutions formed by the heat of the intrusive granitic rocks.

In the larger limestone lenses there are some caves of interest. One of these is at Cave City. The depth of the lowest cavity visited is about 40 feet below the mouth of the cave. There are several chambers, separated by low passages. Some of the stalactites are flange-like; others are in chandelier-like groups; still others resemble curtain-hangings. On some of the shelves of limestone are shallow, saucer-like basins with convoluted borders.

Mariposa slates.—There are two well-marked belts of rocks of this age, one lying east of the Bear Mountains, between the western and the eastern belts of the Calaveras formation, and one west of the Bear Mountains.

The western belt extends across the area of the sheet from the northwest corner southeasterly, through Salt Spring Valley. This belt is continuous with that shown on the Sacramento sheet, which practically terminates at Folsom. Belemnites were found in this slate in Salt Gulch, 4½ miles north of Valley Springs, and these probably indicate the Mariposa era (Upper Jurassic). North of the Calaveras River this area of clay-slates is separated into two main portions by a belt of amphibolite-schist, which has an average width of 1½ miles. The slates west of this amphibolite-schist belt are largely covered by the clay and sandstone of the Ione formation.

The slates of the belt lying to the east of the Bear Mountains are much the same in general lithologic character as those of the western belt. They differ chiefly in containing much augitic and feldspathic material, apparently thrown out as volcanic ashes, which indicates that volcanic eruptions were taking place when the beds were being deposited. An ammonite was found in the slates in the Lincoln mine in Amador County, and another on a branch of Cherokee Creek in Calaveras County. Aucella, ammonites, and belemnites were collected at the western edge of the belt at the Texas ranch, which lies about 5 miles southwest of Angels to the west of Angels Creek, and along the Stanislaus River south of the Texas ranch. According to Professor Hyatt, the ammonites from the localities last mentioned belong to the genera *Cardioceras* and *Perisphinctes*; the species being similar to Upper Jurassic forms of Europe. This same belt extends southeasterly across the area of the Sonora sheet, through Bear Valley in Mariposa County, where aucella, ammonites, and belemnites have also been found.

The Mother lode quartz vein intersects for a great portion of its course this eastern belt of the Mariposa slates. The most important quartz mines of Amador County and the Gwin mine of Calaveras County are in these slates.

ALTERED VARIETIES OF IGNEOUS ROCKS.

Amphibolite-schist.—Large exposures of green schists occur in the area of the Jackson sheet. In places they grade into igneous rocks of the diabase series in such a way as to indicate that they are derived from rocks of the diabase and porphyrite series. These schists are shown by the microscope to be largely made up of green, fibrous hornblende, but they contain in places remains of the augite and feldspar of the diabase and a good deal of biotite and chlorite. Much of the amphibolite-schist appears originally to have been augitic tuff, or volcanic ash of diabase, and some of the amphibolite-schist may have formed from gabbro and diorite.

Amphibole-talc-schist.—Rocks of this series occur usually as narrow streaks representing former basic dikes. In the area of the Jackson sheet these rocks have been noted only in the eastern belt of the Calaveras formation. In some cases the amphibole of the dikes is plainly derived from pyroxene. It is usually nearly colorless, and then seems to correspond to tremolite; sometimes it is slightly greenish. Occasionally serpentine is associated with the amphibole and talc. Portions of the dikes are now altered to talc rock, or soapstone, the largest body of which lies 2½ miles northeast of Angels, forming a circular area about one-third of a mile in diameter.

UNALTERED VARIETIES OF IGNEOUS ROCKS.

Diabase and porphyrite.*—Forming large dike-like areas, with a northwesterly trend, like that of the enclosing sedimentary rocks, is a series of hard, green rocks, with irregular outcrops, which frequently show a tendency to a roughly schistose structure. The rocks of considerable portions of these areas are fine-grained, with large, nearly square, dark crystals of augite, forming an augite-porphyrite; other portions are largely made up of angular fragments, and form a diabase-breccia. Frequently the fine-grained rocks show no large augites but under the microscope are seen to contain large feldspars in a finer groundmass, in which there is some augite; such portions may be designated simply porphyrite. Occasional specimens show no groundmass, but are granular in structure, and are composed of lath-like plagioclase and augite, constituting a typical diabase. The largest area of the diabase series lies just west of the Mother lode belt of Mariposa slates and just east of the western belt of the Calaveras formation. Its southern end forms the point west of Angels, about 2,900 feet high, known as Bear Mountain. It is continuous with the Logtown Ridge area of the Placerville sheet, and it has a maximum width west of Jackson of 2 miles.

The general shape and position of this long area suggest that it is an intruded or an interbedded sheet between the Calaveras formation and the Mariposa slates. West of Golden Gate Hill a portion of this area penetrates, in a dike-like manner, the Calaveras formation, there, without doubt, of Carboniferous age; other portions west and northwest of Golden Gate Hill and elsewhere seem to be dikes in the Mariposa slates. A careful study has not been made of this area, a large part of which is fragmental. The dikes may in all cases prove to be massive. Some of the isolated, dike-like areas in both the Calaveras formation and the Mariposa slates are probably interbedded diabase-tuffs.

These tuffs are presumed either to have been thrown out as volcanic ashes or to have issued as mud-flows at the time the enclosing sedimentary beds were being deposited. Such is a portion of the large, forked diabase area in the Mariposa slates north and east of Amador. Since this tuff grades into the Mariposa clay-slates, there may be some difference of opinion as to where the contact line between the igneous and sedimentary material should be drawn. The exact outlines of these diabase-tuff areas may hereafter be somewhat modified.

The high western ridge of the Bear Mountains is also of diabase. At the western base of this ridge and in its northwestern extension the diabasic rocks have been converted by pressure and other causes into amphibolite-schist, and this is also true of the northwest extension of this area. The small diabase area west and southwest of Ione and the diabase and porphyrite rocks of the Gopher Ridge appear to have undergone very little compression, and perhaps are among the latest of the diabase eruptions, probably belonging to the close of the Juratrias. The same is true of the high eastern ridge of the Bear Mountains and of part of the diabase of the high western

* This term is used in this text to include all the augitic porphyrites, and their tuffs, as well as true diabase. Typical diabase is rare in the area of the Jackson sheet.

ridge of the same group of hills. In some conglomerates in the western area of the Calaveras formation pebbles of porphyrite were found, showing that some porphyrite is pre-Mesozoic in age, and the fragmental diabase and porphyrite areas in this same belt of the Calaveras formation give evidence of eruptions in Carboniferous time.

The magma of Gopher Ridge is an extremely variable one. Certain portions are diabase and augite-porphyrite; other portions—and this is true of perhaps the larger part of the area—contain little augite, but occasional quartz crystals. In portions of the area the rock is typical quartz-porphyrite, as, for instance, in the highest part of the ridge south of the Salt Spring reservoir, and along the western base of the hills to the east of Milton. The quartz-porphyrite south of Rock Creek grades into a porphyrite with very little or no quartz, and this, by the addition of augite, passes into rocks of the diabase series. A separation of the quartz-porphyrite from the augitic porphyrites was not made in the Gopher Ridge area, except at its west base, east of Milton and north of Jenny Lind. Some of the quartz-porphyrite is, however, plainly later than the augitic porphyrite series, for at two points it was noted as unquestionable dikes in that series. One of those dikes is in the bed-rock of the gravel mine 2 miles east of Jenny Lind, and the other 3 miles southeast of Jenny Lind. The coarsely crystalline, granitoid quartz-porphyrite at the western base of Gopher Ridge may likewise be later.

About 1 mile northeast of Towers ranch, in Salt Spring Valley, is a dike of coarse, ophitic diabase in amphibolite-schist that appears to have originally contained olivine which is now converted into serpentine. This dike is not noted on the map.

Hornblende-porphyrite.—The only area of rock laid down on the geological map as hornblende-porphyrite occurs in the Calaveras formation, 1 mile a little west of south from Sugar Loaf. This is quite similar to the hornblende-porphyrite associated with diabase farther north, some areas of which are shown in the western belt of the Calaveras formation on the southern portion of the Placerville sheet. These rocks appear to represent the Neocene hornblende-andesites, and may be considered surface lavas, although some of them occur as dikes, as do the hornblende-andesites. As noted under diorite, some of the modifications of that rock seem essentially hornblende-porphyrite, but are unquestionably intrusive.

Quartz-porphyrite and quartz-porphyrite-schist.—Occurring usually as dike-like masses in the amphibolite-schist and diabase and porphyrite areas are light-colored rocks, sometimes schistose, sometimes massive, which usually contain numerous porphyritic quartz crystals. The quartz-porphyrite appears in some cases to be intrusive in the diabase; in other cases, as in portions of the Gopher Ridge, there is a gradation between them. A portion of the quartz-porphyrite to the north of Jenny Lind and at a point 1½ miles southeast of Milton has a very coarse, holocrystalline groundmass and contains some hornblende. It resembles, and is locally called, granite.

Gabbro.—This rock occurs at several points in the area of the Jackson sheet, but nowhere in large masses. It is one of the latest of the Juratrias eruptives and seldom exhibits schistosity, but the diallage is frequently altered to hornblende. It occurs, in rounded or irregular areas, chiefly in the western belt of the Calaveras formation. The isolated hill that lies 1½ miles north of Sugar Loaf, in Amador County, is composed of a micaceous gabbro. Another area is 3 miles a little south of west from Jackson. Gabbro associated with serpentine occurs 2 miles northwest of Elkhorn station in the Bear Mountains. In the same association 1 mile farther northwest, it contains mica and quartz in a portion of its mass, forming a quartz-mica-gabbro. A small body of gabbro lies just west of the serpentine dike by the road at the village of Carson Hill; and there is some also just east of the narrow serpentine dike that crosses Cosgrove Creek 4 miles northeast of Valley Springs.

Gabbro-diorite.—The gabbro area that lies 4½ miles west of Jackson and south of the Mountain Spring House contains primary hornblende. The coarse-grained portion of the rock may be designated a hornblende-gabbro; the fine-grained, western portion, extending south as a dike, contains very abundant hornblende needles and very little pyroxene, approaching in composition a diorite of the camptonite series.

Gabbro-pyroxenite.—The intrusive granular rock of the area about Whitmore's, in the northeast corner of the sheet, is a very variable one. The larger part is a gabbro. Portions of the mass contain olivine, forming an olivine-gabbro; other portions contain only pyroxene, forming pyroxenite. Some of the pyroxenite is entirely altered to hornblende rock. Brown mica occurs locally, forming a mica-gabbro. A specimen from one point contains primary quartz, brown mica, plagioclase, and pyroxene, with secondary hornblende, forming a kersantite. On the south slope of Mount Crossman the stage road crosses a dark rock composed chiefly of primary brown hornblende. This was thought to be connected genetically with the gabbro.

Pyroxenite.—As is indicated in the preceding paragraph, this rock is sometimes associated with gabbro. It is usually found in or along the borders of serpentine dikes, and in some cases the pyroxene may be seen under the microscope to be altering to serpentine. An area of pyroxenite lies 3 miles south of Railroad Flat, by Esperanza Creek. In a portion of this area the diallage is entirely altered to hornblende. The rock of the area noted 1 mile south of east from Whitmore's is believed to have been pyroxenite, though it is now largely or entirely hornblende. Pyroxenite occurs at the east edge of the serpentine area on Stony Creek 3½ miles northeast of Buena Vista, and the small serpentine area 4 miles southwest of Harmon Peak contains colorless amphibole (tremolite) that was probably derived from pyroxene.

Serpentine.—This rock has everywhere been considered an alteration product of other rocks, usually peridotite, olivine-gabbro, and pyroxenite. At several points in the Jackson-sheet area gabbro and pyroxenite have been noted associated with serpentine and undergoing alteration to serpentine. Some of the serpentine, however, has probably resulted from the alteration of diabase and amphibolite-schist. In the area covered by the Jackson sheet serpentine usually occurs in large dike-like masses. It is most abundant along the western border of the western belt of the Calaveras formation, where the shape and position of the bodies suggest that they represent dikes intrusive in part in the Calaveras formation and in part along the contact between the rocks of that formation and the amphibolite-schist to the west. The long, narrow area of serpentine in the diabase of the western ridge of the Bear Mountains seems to be a dike in the diabase, and therefore of later age. The serpentine belt east of Valley Springs is at one point 1½ miles wide. The belt contains patches of diabase and amphibolite-schist, and much impure serpentine. It is possible that portions of this mass are alteration products of diabase and amphibolite-schist. A considerable part of the serpentine northeast of Valley Springs has undergone silicification and has been converted into a brown, flinty rock containing veins of chalcedony and moss agate. Some of the serpentine dikes in the Calaveras formation west of the town of Sutter Creek are associated with rocks of the diabase series which appear to be undergoing alteration to serpentine. A large serpentine mass entirely surrounds the granodiorite area 3 miles south of Elkhorn station, in the Bear Mountains. The contact between the two rocks is sharp.

Granodiorite (*Quartz-mica-diorite*).—There are several isolated, irregular areas of granodiorite shown on the Jackson sheet, chiefly in the eastern portion of the Calaveras formation. The largest of these is that about Mokelumne Hill, and another nearly as large lies east of San Andreas. The area of granodiorite in the Bear Mountains is entirely surrounded by serpentine. In the vicinity of Rich Gulch, in Calaveras County, are several masses of granodiorite intruded into the mica-schists of the Calaveras formation. The granodiorite area east of Plymouth is a tongue of the Cosumnes granodiorite area of the Placerville sheet. It has been intruded as a dike between the amphibolite-schist just east of the Mariposa slate belt of Plymouth and the eastern belt of the Calaveras formation. The largest area of granodiorite represented on the sheet is that about West Point, in the northeast section, and from an economic standpoint it is also the most important, since it contains numerous gold-quartz veins. It extends into the area of the Big Trees sheet, and may be connected with the immense mass which forms the crest of the Sierra. The granodiorite of the West Point area contains numerous small, black dikes, which are described under the heading Diorite, below.

Granite.—About 4 miles northeast of Jackson is an area of granular rock composed of quartz, plagioclase, orthoclase, black and white mica, epidote, and garnet. The rock resembles closely typical granite. The garnet, which is not an ordinary constituent of granite, is primary, in some cases occurring as inclusions in the orthoclase. The area is over 3 miles long and about 1 mile wide, the maximum diameter having a trend south of east, which corresponds nearly with the strike of the enclosing schists. One specimen of a schist from near the granite contact contains tourmaline, presumably a product of contact-metamorphism. At a point a little more than a mile northwest of Clinton, a vertical vein of quartz in this granite has been prospected and shown to contain gold. Some of this granite is quarried.

Quartz-muscovite rock.—Forming a dike in the Calaveras formation about 2 miles a little north of east from San Andreas, is a granitoid rock that is shown by the microscope to be composed of quartz and a colorless mica, presumably muscovite. Another dike of a similar rock, too small to be noted on the map, was found in the mica-schists about 4 miles east of Plymouth; and a rounded mass, in large part muscovite, occurs eight-tenths of a mile northwest of Volcano, just south of the large andesite-breccia area.

Diorite.—At numerous places in the Jackson area are narrow dikes of medium- to fine-grained dark rocks which usually show to the naked eye abundant hornblende needles. Under the microscope these rocks are seen usually to be composed chiefly of primary brown or green hornblende and feldspar, the latter frequently much decomposed. These rocks seem closely related to camptonite. A portion of the largest area, 2 miles northwest of Volcano, might be called hornblende-porphyrite. An area 1 mile long was outlined 2 miles southwest of Rich Gulch. Several small dikes are indicated between Railroad Flat and Mountain Ranch. At Cave City a diorite is intrusive in the limestone. A lens of diorite occurs in the granodiorite one-half mile northeast of Mokelumne Hill. Dikes of a black, fine-grained diorite or hornblende-porphyrite occur in the granodiorite about West Point, where gold-quartz veins are said to be richer along these dikes. Diorite was also noted cutting rocks of the diabase series near the Cosumnes River, in the Placerville-sheet area.

Since they occur as dikes in granodiorite, itself one of the latest of the Juratrias igneous rocks, it is probable that these diorites represent the very latest of the Mesozoic eruptives.

SUPERJACENT SERIES.

This series consists of late Cretaceous, Eocene, Neocene, and Pleistocene sediments lying unconformably upon the Bed-rock series, together with igneous rocks of the same periods.

NEOCENE PERIOD.

Ione formation.—Along the western border of the metamorphic rocks is a series of nearly horizontally stratified, light-colored sediments, which were deposited in the waters that covered the Great Valley at the time the older auriferous gravels with interbedded pipe-clays accumulated in the river beds of the Sierra slope.

This formation attains its maximum development in the area of the Jackson sheet. The lower portion of the series, composed largely of white clay, is well exposed around Ione, whence the formation takes its name. Farther south the white clays are overlain by sandstone, above which is a fine-grained clay rock. The lower, white clay is in places quite free from grit and is used in making pottery. Other portions are sandy. The formation contains iron-ore and coal seams. The sandstone is used for building purposes. It is usually white, but at one quarry a brick-red variety, colored by finely disseminated hematite, is obtained. At other localities it is rusty and contains pebbles of white quartz, passing into a conglomerate. A peculiar hydrous silicate of alumina occurs abundantly in the sandstone in the form of cream-colored, pearly scales.

The clay rock occurring above the sandstone is light-gray, but usually more or less discolored. The fracture is, as a rule, irregular, and the rock frequently contains minute, tubular passages. Under the microscope it is seen to be composed of fine particles of feldspar and fine, discolored sediment, with occasional quartz grains. Analyses of two specimens gave 59 and 72 per cent of silica and 4.8 and 1.6 per cent of alkali.

The succession of white clay, sandstone, and clay rock may not be constant throughout the entire area mapped as belonging to the Ione formation. It has been suggested that the white clay of the lower beds was formed from rhyolitic tuffs, in which case eruptions of rhyolite must have occurred at the beginning of the Ione epoch.

The thickness of the Ione formation is known partly by natural exposures, partly by boring. In Jones Butte the strata, protected from erosion by a lava cap, are 200 feet thick above Coal mine No. 3. A boring at the mine is said to have penetrated sandy clay to a depth of 800 feet below the coal seam, which is 60 to 70 feet below the surface. Thus the Ione beds appear to be more than 1,000 feet thick at this point.

To the east of Buena Vista Peak the series has a visible thickness of 600 feet. The table-land south and southwest of Buena Vista is chiefly composed of the Ione formation, overlain by rhyolitic and andesitic tuff and Neocene shore gravels. The lower clay occurs at the east base of the table-land, and a patch of Ione sandstone caps Waters Peak, a little farther east, which has an elevation of about 900 feet.

The relation of the sandstone to the clay rock is finely exposed on the south side of the Mokelumne River, by the bridge north of Camanche. Here the sandstone forms the lower part of the bank of the river. The upper surface of the sandstone has a gentle westerly dip, and a little west of the bridge reaches the level of the river, which at this point is about 175 feet above sea-level. East of the bridge it rises at an angle of about 1°, reaching an altitude of 1,000 feet on the flat ridge just north of Valley Springs Peak. Along the banks of the Mokelumne west of Lancha Plana this sandstone attains a thickness of more than 100 feet.

NEOCENE GRAVELS.

In the Jackson area the gravel deposits of the Neocene period fall into two classes: the auriferous river gravels and the non-auriferous shore gravels. The former differ in age, and are distinguished as earlier or later river gravels according to their position beneath flows of rhyolitic tuff or above the rhyolite and in association with andesitic flows. The shore gravels form continuous deposits with some of the latest river gravels, but they are recognized separately because they were spread by waves of the gulf which then occupied the Valley of California.

Auriferous river gravels.—The Neocene river gravels occur chiefly on the ridge tops, and are frequently covered by a capping of volcanic material. Where the gravel beds have no covering it is usually evident that the overlying volcanics have been eroded.

The older gravels, composed chiefly of white quartz pebbles, are usually overlain by rhyolitic tuff. Such are the beds on the ridges north and south of Dry Creek east of Plymouth, and at Chili Gulch. At the latter place much of this earlier gravel is consolidated into a quartz-conglomerate, and some of the finer sediments into a sandstone. It is altogether probable that the channels in which these older gravels were deposited represent the river system of late Cretaceous, Eocene, and early Neocene time, although all the plant remains—chiefly leaves from the layers of clay—indicate the age to be Neocene. These gravels appear to have been formed at the same time that the Ione formation was being deposited in the waters of the Great Valley.

The later gravels date from the epoch of the andesitic eruptions, that is, from the latter part of the Neocene. These are later than the rhyolitic flows, and contain andesitic pebbles, often in great abundance. In places, as north of Angels, these gravels overlie the rhyolite and contain rhyolitic pebbles. The gravels south of Drytown, south of San Andreas, and 1 mile north of Jackson are examples of this later series. The Central Hill gravels, 3 miles northwest of San Andreas, and their continuation south of Cottage Spring, appear to belong chiefly to the later series, although, as the older Chili Gulch river found its outlet here, some earlier gravels are probably present.

Associated with the gravel beds of the Central Hill area at a point one-fourth of a mile northeast of North Branch is some andesitic tuff or andesitic sandstone. The gravel about the town of Railroad Flat has been represented on the map as of Neocene age, chiefly because of its position high above the present south fork of the Mokelumne River. The large size of the pebbles and their likeness to rocks in place in the neighborhood indicate that they have not been transported far. Much of the material is subangular, some of it not rounded at all, and the well-worn pebbles may be largely derived from an older channel. There is much red soil mixed with this gravel. Just southeast of Railroad Flat, and also about 1 mile northwest, by the road to Glencoe, is some stratified river material—sand, gravel, and clay—which probably represents an older river system. The later coarse gravel that forms most of the two areas represented on the map is at a higher level than these deposits. About eight-tenths of a mile northwest of Railroad Flat the road to Glencoe passes over an area of rhyolite, and just north of this the coarse gravel which has been mined may be seen at one point to lie against the rhyolite, and contains pebbles of rhyolite, so that there is no doubt that this gravel is later than the rhyolite.

The Lampson channel, 2 miles south of Railroad Flat, is covered with rhyolite. It lies below the general level of the bed-rock surface of the district and belongs to the older gravels. The gravel that is crossed by the road to Mountain Ranch, one-fourth of a mile south of the Lampson mine, is at a higher level and is probably of the age of the later gravel at Railroad Flat.

There is much scattered gravel about the headwaters of Esperanza Creek, and this district evidently represents a Neocene valley in which the Pleistocene rivers have not eroded deep channels. All of this valley appears to have been covered at one time by rhyolite-tuff.

The two gravel areas 1 mile and $1\frac{3}{10}$ miles northeast of Aqueduct, in Amador County, by the road to West Point, resemble the Railroad Flat gravel in being composed of red soil through which pebbles are scattered.

The course of the Neocene drainage of the Jackson-sheet area has not been worked out carefully. Then, as now, the Bear Mountains were a barrier to the streams east, and deflected them to the northwest. Between Golden Gate Hill and Jackson, the hard diabase ridge west of the town of Mokelumne Hill appears to have turned the Neocene streams to the south, where, uniting with the streams of the region east of the Bear Mountains, they found an outlet a little north of the present channel of Calaveras River into the waters that then covered the Great Valley of California.

The old river channels east of Plymouth appear to have found their way to the Neocene gulf more directly, probably passing south of Plymouth.

The area 2 miles northeast of Plymouth represents both the earlier and the later gravels. The older deposit, on top of a hill 1,600 feet high, consists of a quartz conglomerate similar to that at Chili Gulch. It includes fine layers that contain silvery-white flakes of a hydrous silicate of alumina, which is abundant in the sandstone of the Ione formation. There is a little rhyolite on this hill, but its relation to the conglomerate is not evident. A later deposit of coarse gravel, which has been washed for gold, occurs north and south of this quartz conglomerate. It contains bowlders of granodiorite, which here forms the bed-rock. Gravel of the same age has been hydraulicked on the ridge one-half mile south. The bottom gravel of this exposure contains pebbles of granodiorite, slabs of micaceous quartzite, which is here the bed-rock, and a few rhyolite pebbles.

Since the Neocene river system existed from the epoch of the earliest to that of the latest river deposits, it follows that the gravel beds form a more or less continuous series. There has been no attempt to separate on the map the earlier Neocene river gravels from the later.

The gravel channel marked on the map as crossing Chili Gulch 1 mile a little north of east from Golden Gate Hill is not visible on the surface. It has been brought to its present position by faulting, the downthrow amounting to perhaps 200 feet. At its southwestern end this channel comes squarely against the bed-rock, composed here of slates. A shaft sunk to strike this faulted gravel bed, according to a resident miner, passed through about 150 feet of fine material, under which was found 6 feet of gravel.

Neocene shore gravels.—Overlying the Ione formation and forming level tops to the ridges are conglomerate and gravel beds, best seen west and southwest of Valley Springs. This conglomerate contains a considerable variety of pebbles; quartzite, mica-schist, quartz-porphyrite, granitoid rocks, andesite, and rhyolite-tuff being represented. Rhyolitic pebbles are so frequent as to be characteristic of the material in places. At a few points small amounts of andesitic sandstone are associated with these gravel and conglomerate beds.

The gravels appear to have been deposited in the waters of the great gulf, and not being in general auriferous, have been separated from the Auriferous river gravel series and called Neocene shore gravels. The Neocene shore gravels to the east of Valley Springs are continuous with and of the same age as the Auriferous gravels immediately east, about Cottage Spring and Central Hill.

On the slopes of the peaks of Buena Vista and Valley Springs this series evidently rests unconformably on the rhyolite-tuff. In a cut of the San Joaquin and Sierra Nevada Railroad 1 mile southwest of Valley Springs the gravels are well exposed and attain a thickness of 200 feet. At the bottom of the deposit in the cut there may be seen irregular blocks of the gray clay rock of the Ione formation, and the gravel includes one or two thin layers of white sandstone which can not be distinguished from the sandstone at the Late quarry west of Valley Springs. The two small areas of gravel south of Rock Creek, on the west slope of the Gopher Ridge, are probably shore gravels. After the deposition of the Ione formation, and after the rhyolitic lava-flows, there was a period of erosion, during which the strata of the Ione formation were carved into flat-topped hills, with benches at various levels. The later Neocene shore gravels contain numerous pebbles of rhyolite, formed at the time, and the gravels were deposited on the top of the flat-topped hills, on the benches on their slopes, and in the depressions between the hills. The most striking evidence of nonconformity, however, may be seen at the red sandstone quarry 3 miles southeast of Buena Vista. Here the Neocene shore gravels rest unconformably on the smooth, waterworn surface of the sandstone, which is red where quarried, but white at the northern end of the exposure. Waterworn bowlders of the white sandstone may be seen in the gravel. Southwest of the quarry the ridge is capped for a distance of more than a mile with the same gravel, which half a mile from the quarry contains a layer of andesitic detritus. At the extreme southwestern end of the ridge is a body of similar gravel, which also rests plainly on sandstone of the Ione formation.

Just south of this gravel is an area of andesitic tuff which caps some conglomerate containing pebbles of rhyolite, quartzite, hornblende-andesite, etc., with a matrix of andesitic tuff. It is presumed that the conglomerate and gravel under the andesite here are continuous with the Neocene shore gravels just described and are of the same age. The flat-topped hill west of Jones Butte offers a very similar section. The hill is capped with andesitic breccia, under which is a bed of coarse conglomerate containing pebbles of hornblende-andesite, rhyolite, quartzite, and granite. Beneath the conglomerate are fine tuffs, and the clay of the Ione formation forms the base of the series. The Neocene shore conglomerate and gravel may therefore be correlated with the conglomerate layers that underlie the andesitic breccia, and it then becomes probable that andesitic tuffs or breccia formerly covered all of the areas of the Neocene shore gravels about and southwest of Valley Springs. In fact, the flows of andesite may have extended over almost all of the area of the Jackson sheet except the Bear Mountains and Gopher Ridge.

The gravel 2 miles northeast of Angels, which is mapped as Auriferous river gravel, differs little in composition from the Neocene shore gravel about Valley Springs. It is unconformable on rhyolite-tuff, and contains pebbles of that material. It is thought to be of the same age as other late Neocene river gravels, from which it differs in composition chiefly in containing a greater number of rhyolitic pebbles. This is easily explained by the abundance of rhyolite-tuff in both districts, from which the pebbles were formed.

The Neocene shore gravels by the creek 3 miles south of Burson appear to have been brought to their present position by a downward displacement of perhaps 100 feet. They are composed of pebbles similar to those in the gravels on the ridge south and east.

NEOCENE VOLCANIC DEPOSITS.

Rhyolitic beds.—Covering the gravels of the old river channels in many places are white stratified deposits, in part fine clays (called pipe-clays) with some sand and gravel, but chiefly rhyolite-tuff. The pipe-clay is probably decomposed rhyolitic material, and it is chiefly in this clay that the leaves have been found which have given a clue to the age of the old river channels. Most of these leaves have been referred to the early Neocene (Miocene).

The rhyolite-tuffs also occur overlying the Ione formation in the low foothills near the Great Valley. The sources of the rhyolitic flows seem to have been largely in the higher mountains east of the Jackson-sheet area. Valley Springs Peak, however, may have been a source of eruption, for in a gulch on its north side no rock underlying the rhyolite is exposed.

Analyses of three specimens of the rhyolite-tuff of the Jackson-sheet area gave 69.5 to 71.8 per cent of silica, 4.1 to 5.1 per cent of potash, and 0.8 to 1.8 per cent of soda. The largest area noted is that of Buena Vista Peak. Another high point capped by rhyolite-tuff is the table mountain known as Valley Springs Peak. This rhyolite in part overlies gravel, which is well exposed by a tunnel at the southwestern side of the bluff. The gravel is cemented by a coarse, gray sand, and contains pebbles of quartz, quartzite, quartz-porphyrite, and black slate, but none of Neocene volcanics.

The rhyolite 1 mile southwest of Jackson Butte is fragmental, containing some pebbles of andesite and fragments of the neighboring diorite. Here, entirely surrounded by rocks of pre-Tertiary age, is a basin which must have been formed since the deposition of the Neocene river gravels, for these occur at a greater elevation on the surrounding ridges. This area appears to have been formed by rhyolitic and andesitic detritus which was washed into the basin, and the formation is therefore in no sense a lava-flow. Shafts, one of them 220 feet deep, are said to have been sunk in this basin without striking bed-rock. Covering the rhyolitic detritus are Pleistocene gravels, which have been mined extensively for gold.

There is a large amount of rhyolite-tuff overlying the gravel channels south of Mokelumne Hill, northeast of Angels, on the ridges about Dry Creek east of Plymouth, and in an area shown northeast of Mountain Ranch, and it is at the latter locality that the rhyolite-tuffs attain their maximum thickness, which at one point is 400 feet.

Rhyolitic tuff overlies the Ione clay rock at Valley Springs and Buena Vista peaks, and also at other points, some of which are noted on the geologic map. On account of the difficulty of distinguishing some of the rhyolitic tuff from the Ione clay rock, it is likely that a few areas of the former have escaped detection.

Andesite.—Forming level tops to many of the ridges shown on the Jackson sheet, and covering extensive areas in the lower foothills, are beds of fragmental andesite, more or less roughly stratified. The lower layers are often of andesitic gravel, with some pebbles of pre-Cretaceous metamorphic and igneous rocks, and with beds of andesitic tuff, which in the lower foothills often contains quartz grains. The top layer of the series, when preserved, is everywhere a breccia, containing large and small angular fragments of andesite, and sometimes bowlders of granite that were evidently brought down from the higher mountains. These volcanic deposits are believed to have come down largely in the form of mudflows from volcanoes along the summit of the range. There is evidence that late in the Neocene period the Great Valley of California was a gulf or inland sea, and the andesitic gravels and tuffaceous sandstone of the lower foothills were doubtless stratified in part by the waters of this gulf. But even in the shore deposits, gravels and tuffs make up the lower layers, and the breccia forms a hard cap to the whole, as may be seen in the flat-topped hills one-half mile northwest of Ione, shown on the Lodi sheet, or in the flat-topped buttes of the andesitic mesa southwest of Buena Vista Peak. Compact hornblende-andesite occurs at only three points on the Jackson sheet—at Jackson Butte, Golden Gate Hill, and the butte locally called Tunnel Peak, $1\frac{1}{2}$ miles southwest of the town of Mokelumne Hill. It is possible that these were vents through which the lava escaped and in which it congealed.

There is evidence that a period of erosion occurred between the rhyolitic flows and the andesitic eruptions. In a cut made for mining purposes one-fourth of a mile northeast of Altaville and just north of the road to Murphy's is exposed an old stream bottom eroded in rhyolitic tuff, the polish of the waterworn surface still being preserved. This channel is filled with andesitic tuff and conglomerate. Additional evidence of erosion is found in the occurrence of rhyolitic pebbles in the Neocene shore gravels, which appear to be of the same age as the gravels of the andesitic series. That the flows of andesitic breccia occurred later than those of the rhyolite is evident wherever the two are in contact, for the fragmental andesite invariably overlies the rhyolite. This is apparent on the ridges north and south of Dry Creek, about Chili Gulch south of Mokelumne Hill, and to the south of Railroad Flat.

Analyses of three specimens of andesite-tuff gave 54.1 to 59.5 per cent of silica, 1.5 to 2.3 of potash, and 2.7 to 3.7 of soda.

PLEISTOCENE PERIOD.

Earlier Pleistocene.—The river deposits of this age consist of gravels, which are spread in the canyons of the present rivers and usually occur less than 100 feet above the present river level. These old river gravels are frequently auriferous. The gravels of the area $1\frac{1}{4}$ miles west of Jesus Maria, north of the north fork of the Mokelumne River, and of that just north of the Calaveras River and east of the mouth of Cosgrove Creek, are of this age, as well as those that have been extensively hydraulicked at Lancha Plana.

One mile west of Lancha Plana the Mokelumne River formerly occupied a channel a little south of its present position. This old river bed is followed by the road from Lancha Plana to Camanche. The gravel contains waterworn bowlders of the Ione sandstone, which formed the banks of the old stream, as it now forms those of the present stream.

The early Pleistocene gravels were to a great extent washed away as the rivers gradually eroded deeper valleys, and they now form part of the present river gravels.

The gravels that have been extensively mined for gold at Butte City, 1 mile southwest of Jackson Butte, are probably of Pleistocene age, and may have been deposited late in the period. They overlie rhyolitic detritus, and, like the rhyolite, have been washed into a basin from surrounding areas.

The siliceous gravels that cover considerable areas in the foothills at the edge of the valley are also of early Pleistocene age. They are formed largely of Neocene gravels, which have been so washed that the softer, volcanic pebbles have been almost completely worn away, leaving the harder, siliceous pebbles.

Early Pleistocene shore gravels form the tops of many of the low table-lands of the foothills. They rest unconformably on the clay, sandstone, and clay rock of the Ione formation, and on the andesite-tuff series as well. The gravels that have been washed for gold at Irish Hill (4 miles northwest of Jackson), about Camanche, and at the North Hill mine (south of Jenny Lind) are thought to be of this formation. At some points these gravels have been consolidated into a conglomerate. Associated with the early Pleistocene shore gravels are layers of hardpan—a more or less friable sandstone generally discolored with iron and penetrated with difficulty by the roots of plants. The early Pleistocene gravels along the borders of the Great Valley usually form a red soil.

Alluvium.—There are narrow, shallow areas of alluvium in the canyons and ravines at many points shown on the Jackson sheet, and the gravels of these areas are frequently auriferous. The larger areas along the rivers at the edge of the valley are deeper, and usually consist of finer sediment, with little gravel. These form rich soils, but do not as a rule contain a workable percentage of gold.

MINERAL RESOURCES.

Gold-quartz veins.—The slates and schists of the Mariposa beds and of the Calaveras formation, as well as the associated igneous rocks—granodiorite and amphibolite-schist—contain a large number of quartz veins, many of which are highly auriferous. The series of these veins which extends across the sheet in a southeasterly direction from Plymouth, in Amador County, to Carson Hill, in Calaveras County, is called the Mother lode, and includes by far the larger number of the best quartz mines in the Jackson-sheet area.

The quartz veins of the Mother lode may be divided into three classes: those occurring only in the black clay-slates of the Mariposa beds, those occurring along the contact of the black slates with rocks of the diabase series, and those in amphibolite-schist. The Plymouth Consolidated, the New London, and the Gwin mines are examples of the first; the Keystone, South Spring Hill, and Kennedy, of the second; and the Union mine, 3 miles southeast of San Andreas, and the mines at Angels are examples of the third class. There is a little black slate, however, both in the Union mine and in one of the mines at Angels.

In the Mother lode mines the gold occurs in the quartz and in the sulphurets, and the ores are classed as free milling, the sulphurets being separated and chloridized. The sulphurets are mostly iron pyrite, but galena and zincblende are also present. Galena is said to indicate rich ore. In the large mines gold is rarely visible to the eye, it being more or less evenly distributed through the vein material. Almost all the mines, however, afford occasional specimens showing abundance of gold to the unaided eye. The quartz veins of the Mother lode usually follow the strike of the enclosing slates and schists,—that is, they strike northwesterly. The dip of the veins is also frequently that of the enclosing rocks, but there are abundant exceptions to this rule.

In the western belt of the Mariposa slates, extending across the area of the sheet from its northwest corner to Salt Spring Valley and beyond, quartz veins frequently occur, but they are usually small and contain little gold. Some of them, however, between Salt Spring Valley and Copperopolis, have been worked for gold.

The western belt of the Calaveras formation also contains few if any valuable quartz veins. In the wide eastern belt of the Calaveras formation the veins are numerous and large, but they have not usually proved to be so highly auriferous as those of the Mother lode. A marked exception to this rule is the vein of the Sheep Ranch mine, which is in mica-schist.

The large quartz vein of the Ilex mine at Rich Gulch has a course about north 80° east, and dips to the south about 85°. The country rock is a mica-chlorite-schist, and small amounts of the sulphides of iron, copper, lead, zinc, and antimony occur in the ore, some of which shows gold to the naked eye. This vein was very thoroughly prospected and found not to contain a workable quantity of gold. Many other quartz veins in this eastern area have been worked for gold, with varying success. Frequently the smaller quartz veins of the area are very rich in spots, forming what are called "pocket mines." They vary much in strike and dip. The gold of the rich placers at Pine Grove, Volcano, Rich Gulch, and other points doubtless came largely from these small quartz veins.

The granodiorite also contains valuable gold-quartz veins. In the Jackson-sheet area these are most frequent about West Point. The ores are usually very base, containing large amounts of iron pyrite and pyrrhotite. Cutting the granodiorite of the West Point area are numerous small, black dikes sometimes showing to the naked eye hornblende needles. This rock is a diorite or hornblende-porphyrite. The ore in the Lockwood mine is said to have been richer where the vein was crossed by one of these dikes.

Very few quartz veins occur in the diabase and porphyrite areas, although, as before stated, they are frequent in the amphibolite-schist—a dynamometamorphic form of these rocks.

Gold-bearing gravels.—Nearly all of the gravels along the streams in the areas of the metamorphic and old eruptive rocks have proved highly auriferous. The same may be said of the early Pleistocene gravels that usually lie in benches above the level of the present streams, as well as of the gravels of the Neocene rivers, now mostly forming tops of ridges or occurring beneath a cap of volcanic material. These higher gravels have been washed by the hydraulic process at many points, notably about the headwaters of Dry Creek in Amador County; 2 miles southeast of Jackson; at Chili Gulch; northwest and west of Campo Seco; and east and southeast of San Andreas. In some cases these old river gravels, as well as some of the shore gravels of the Ione formation, are so consolidated as to require crushing in a stamp-mill before being washed.

The white quartz gravels of the Ione formation have been extensively washed for gold at Muletown (to the north of Ione), 7 miles west of Plymouth, 2 miles southwest of Campo Seco, and at other points.

The early Pleistocene shore gravels also contain gold in paying quantities, particularly in the neighborhood of the mouths of the present rivers and large creeks. These gravels have been washed at a great number of points, as may be seen by the numerous cross-hammers on the economic sheet, but most extensively at the North Hill mine, on the south side of the Calaveras River, opposite Jenny Lind; about Camanche; and at Irish Hill, 4 miles northwest of Ione.

Alluvial gravel is being extensively worked for gold at the Arroyo Seco mine, 3 miles northwest of Ione.

The gravels mined at Lancha Plana are river gravels of early Pleistocene age.

Copper.—Deposits of copper occur in two belts in the amphibolite-schists. The Ione and Caledonia mines and the mines at Copperopolis, with numerous deposits between, form the longer belt, which lies in the schist area just east of the western belt of the Mariposa slates. The other and smaller belt lies west of Campo Seco and contains the mines of the Penn Chemical Company. The ore is chiefly copper sulphide, and some of it is said to contain sufficient gold to pay the cost of reduction. The percentage of iron in the ore is very large.

At one of the Campo Seco mines a quartz-porphyrite dike accompanies part of the vein. Two copper prospects are noted on the map in amphibolite-schist just east of a quartz-porphyrite dike about 3 miles east of north from Campo Seco. The Cosumnes and Oriental copper mines, worked extensively some years ago, occur in quartz-porphyrite $6\frac{1}{10}$ miles northwest of Sugar Loaf, and therefore just north of the Jackson-sheet area. The quartz-porphyrite does not, however, appear to be a regular accompaniment of the copper deposits.

Chrome iron.—In the serpentine there are numerous irregular bodies of chrome-iron ore, which appear usually not to extend to a great depth. However, no deep exploitation of chrome-iron deposits has thus far been made in the area covered by the Jackson sheet. Occurrences of the ore are noted on the economic sheet about 7 miles northeast of Milton and at two points about 5 miles east of north from Valley Springs.

Iron and manganese.—Two miles west of Ione there is a large deposit of impure hematite in the Ione formation. An analysis of this ore yielded 44.59 per cent of metallic iron and 0.23 per cent of phosphorus, with only a trace of sulphur. Some hematite collected about a half mile northwest of Clinton contains 55.78 per cent of metallic iron, and limonite from about a half mile north of the Esmeralda quartz mine on Indian Creek contains 56.9 per cent of metallic iron. The two ores last mentioned are from deposits in the Calaveras formation. There is a deposit of limonite about 1 mile southeast of Campo Seco. Manganese oxide from the Calaveras formation has been found in mica-schist 2 miles northeast of San Andreas.

Ocher.—One and a half miles north of Valley Springs is a body of decomposed slate stained by iron oxide, which forms a durable red paint. This has been used to a considerable extent in the neighborhood.

Coal.—Lignite occurs in the Ione formation in Amador County. At Coal mine No. 3, 4 miles northwest of Ione, there is a lignite stratum about 7 feet thick, which has a dip of about 5° to 7° to the south. Overlying the coal seam is a body of sand and clay, about 60 feet thick, which includes a layer containing imperfect fossil leaves. At a point to the north of the mine the sandy clay underlying the coal was penetrated to the depth of about 800 feet without finding another coal seam. Nearly all of the valley between Ione and Carbondale is underlain by this lignite stratum, as has been determined by borings and shafts. It has been mined also near the railroad to the west of Ione. Some shafts in the hills north of Lancha Plana have struck coal, presumably an extension of the Ione bed. The Ione lignite does not bear transportation well.

Clay.—The white clay of the Ione formation has been extensively quarried to the northwest of Ione and about Carbondale, and used for making coarse pottery. Variegated clay of good quality has been quarried at Valley Springs and shipped to Stockton for making pottery.

Limestone.—There are numerous lenses of limestone in the Calaveras formation, and a large number of these are noted on the economic sheet. Much of it has been found suitable for making lime.

Building stone.—Marble is quarried 2 miles east of Plymouth and 3 miles west of Volcano. The granite of the area that lies 4 miles northeast of Jackson is also quarried. Some of the old buildings at Mokelumne Hill, Angels, and other places are constructed of rhyolite-tuff, which is frequently pink in color. Andesite-tuff has been used near Valley Springs in building houses and for fireplaces. Both of these rocks trim easily when first quarried, and harden on exposure. White sandstone is quarried just southwest of Valley Springs, as is red sandstone from the Ione formation 7 miles southeast of Ione.

Talc rock, or soapstone, occurs in narrow streaks at many points in the eastern area of the Calaveras formation. Some of these are noted on the map. The rock is used locally for fireplaces.

A beautifully mottled serpentine is quarried about $1\frac{1}{2}$ miles west of Sugar Loaf, and used for ornamental purposes.

The porphyrite of Gopher Ridge has been used to some extent in Stockton as a paving stone.

The black clay-slates of the Mariposa beds form a good roofing slate.

Soils.—The richest soils are those of the alluvial areas along the Calaveras and Mokelumne rivers and along Dry and Jackson creeks.

The red soil of the early Pleistocene shore gravels is not very rich. West of Milton and elsewhere these gravel lands are extensively used for raising grain.

The andesite-tuff areas along the border of the Great Valley form rich, black soils, the main crop from which is grain.

The rhyolite-tuff soils are usually rich in potash, and, where sufficiently deep and extensive, are valuable. Such is the soil to the southwest of Buena Vista Peak, where, however, there is a lack of water for proper irrigation.

Probably the poorest soils in the area represented by the sheet are those formed from the clays of the Ione formation.

The red soil from the schists of the eastern area of the Calaveras formation makes fine fruit land, and the same may be said of the soil of the diabase areas.

As a rule, the areas of the Mariposa slates are very dry, and the soils poor and shallow.

Some of the soils of the granitic areas make good fruit lands.

H. W. TURNER,
Geologist.

G. F. BECKER,
Geologist in charge.

U.S. GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR.

TOPOGRAPHY

CALIFORNIA
JACKSON SHEET

LEGEND

RELIEF
(printed in brown)

Figures
(showing exact heights above mean sea-level)

Contours
(showing height above sea, horizontal form and steepness of slopes of the surface)

DRAINAGE
(printed in blue)

Rivers

Creeks

Lakes and ponds

CULTURE
(printed in black)

Towns and cities

Railroads

Roads

Trails

Bridges

County lines

Henry Gannett, Chief Geographer.
A.H. Thompson, Geographer in charge.
Triangulation by H.M. Wilson.
Topography by A.F. Dunnington and R.H. McKee.
Surveyed in 1888.

Scale $\frac{1}{125000}$

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet.

Edition of Mar. 1894.

U. S. GEOLOGICAL SURVEY
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AREAL GEOLOGY

CALIFORNIA
JACKSON SHEET

Henry Gannett, Chief Geographer.
A. H. Thompson, Geographer in charge.
Triangulation by H. M. Wilson
Topography by A. F. Dunnington and R. H. McKee
Surveyed in 1888

Scale 1/125,000

0 1 2 3 4 5 6 Miles

Contour interval 100 feet

Edition of Mar. 1894

Geo. F. Becker, Geologist in Charge
Geology by H. W. Turner.
Surveyed in 1889-91

U. S. GEOLOGICAL SURVEY
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ECONOMIC GEOLOGY

CALIFORNIA
JACKSON SHEET

Henry Gannett, Chief Geographer
A. H. Thompson, Geographer in charge.
Triangulation by H. M. Wilson.
Topography by A. F. Dunnington and R. H. McKee.
Surveyed in 1888.

Scale $\frac{1}{125,000}$

Contour Interval 100 feet

Edition of Mar 1894.

Geo. F. Becker, Geologist in Charge
Geology by H. W. Turner
Surveyed in 1889-91.

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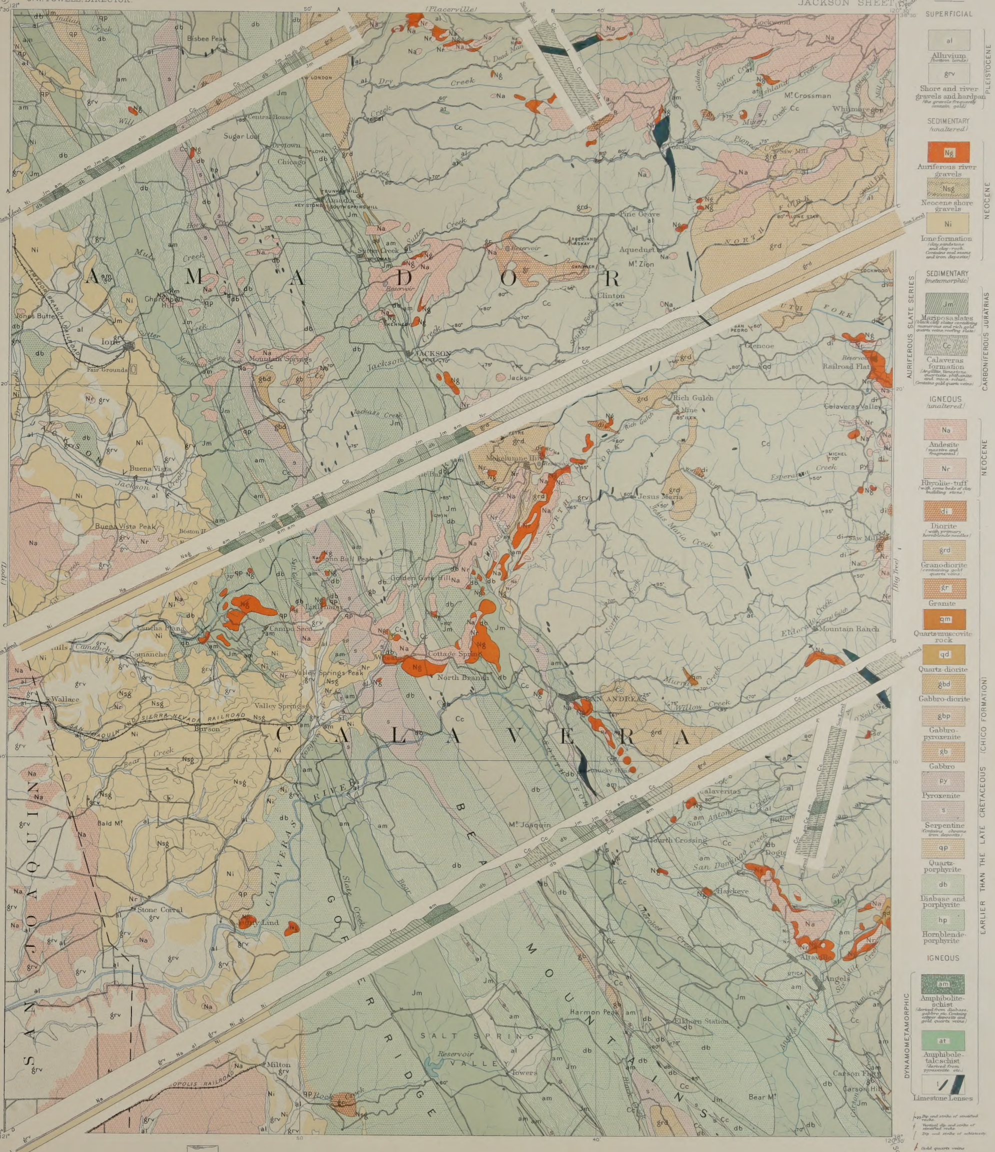
STRUCTURE SECTIONS

CALIFORNIA
JACKSON SHEET



Henry Gannett, Chief Geographer.
A.H. Thompson, Geographer in charge.
Triangulation by H.M. Wilson.
Topography by A.F. Dunnington and R.H. McKee.
Surveyed in 1888.

Scale 1:125,000
0 1 2 3 4 5 6 Miles
Contour Interval 100 feet.
Edition of Mar. 1894.

Geo. F. Becker Geologist in Charge.
Geology by H.W. Turner.
Surveyed in 1889-91.

pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture.*—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales;* but when rocks of any class are found in thin layers that are due to pressure they are called *slates.* When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists,* a term which applies to both shaly and slaty structures.

Rocks of any period of the earth's history, from the Neocene back to the Algonkian, may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known remain in some localities essentially unchanged.

Metamorphic crystalline formations are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines.

If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters only.

USES OF THE MAPS.

Topography.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

Areal geology.—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend,* which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its colored pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

Economic geology.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors.

A symbol for mines is introduced in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

Structure sections.—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial cutting which exhibits those relations is called a *section,* and the same name is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure,* and a section exhibiting this arrangement is called a *structure section.*

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

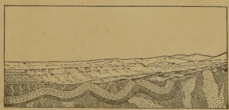


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows the underground relations of the rocks. The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

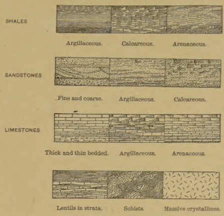


Fig. 3. Symbols used to represent different kinds of rocks.

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thicknesses can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

When strata which are thus inclined are traced underground in mining or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales and limestones were deposited beneath the sea in nearly flat sheets. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable.*

The second group of formations consists of strata which form arches and troughs. These strata were continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first group, being parallel, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata or upon their upturned and eroded edges, the relation between the two is *unconformable,* and their surface of contact is an *unconformity.*

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only relations which actually occur. The sections in the Structure Section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond to the actual slopes of the ground along the section line, and the depth of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

Columnar sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram. The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

J. W. POWELL,
Director.